WHAT IS CLAIMED IS:

1. An apparatus for generating at least one hybrid arc/microwave plasma discharge, the apparatus comprising:

a) a cavity adapted to support at least one of a TE mode and a TM mode at a microwave frequency; and

b) a torch module, coupled with the cavity, for generating seed plasma within the cavity.

2. The apparatus of claim 1, wherein the cavity is a tapered cavity.

3. The apparatus of claim 1, further comprising:

c) a microwave source, coupled with the cavity, for generating microwaves at the microwave frequency, and for introducing the generated microwaves into the cavity.

4. The apparatus of claim 1, wherein the torch module is an arc torch module, and wherein the seed plasma generated by the arc torch module discharge triggers microwave discharge in the cavity thereby generating additional plasma.

5. The apparatus of claim 4 wherein an exit opening is defined in the cavity at a location opposite the arc torch module, wherein plasma is generated by a combination of an arc discharge and microwave discharge, and wherein the generated plasma exits the cavity through the exit opening as the hybrid arc/microwave discharge.

6. The apparatus of claim 1, wherein, said cavity includes a first wall and a second wall opposing the first wall, wherein the torch module is fitted into the first wall of the cavity, and wherein an exit opening is defined in the second wall of the cavity at a location opposed to the location of the torch module.

7. The apparatus of claim 1, wherein said cavity has a narrow section, a wide section, and a tapered section arranged between the narrow and wide sections.

8. The apparatus of claim 7 wherein both the narrow section and the wide section have rectangular cross sections.

9. The apparatus of claim 8, wherein the cavity is dimensioned to support a TE_{10n} mode at the microwave source frequency, wherein n is an integer that is at least 3.

10. The apparatus of claim 6, wherein said cavity includes

- endwalls substantially orthogonal to the first and second wall, and
- additional walls arranged between the endwalls and including the first and second walls,

wherein the hybrid arc/microwave plasma discharge exits the cavity from the exit opening of the second wall.

11. The apparatus of claim 1, further comprising at least one additional torch module coupled with the cavity, wherein the seed plasma generated by the arc discharges of the torch modules is energized by a TE mode electric field rather that by a TM mode, the seed plasma triggering subsequent microwave discharges thereby generating at least two hybrid arc/microwave plasma discharges.

12. The apparatus of claim 11, wherein, said cavity includes a first wall and a second wall opposing the first wall, wherein the torch modules are fitted into the first wall of the cavity, and wherein exit openings are defined in the second wall of the cavity at a location opposed to the location of the torch modules, wherein said cavity includes endwalls substantially orthogonal to the first and second walls, and wherein the hybrid arc/microwave plasma discharges exit the cavity from the two exit holes of the second wall.

13. The apparatus of claim 10, wherein said cavity has a narrow section, a wide section, and a tapered section arranged between the narrow and wide sections,

wherein said cavity includes a narrow section defined by the additional walls, the narrow section having a height of about 5 mm, a first of the additional walls having a first opening defined therein at which the torch module is fixed, a second of the additional walls having a second opening defined therein,

wherein the second opening permits the hybrid arc/microwave plasma torch to exit, and

wherein the first and second openings are located at one of the electric field maximum locations of the TE_{10n} mode, and the tapered section including two end locations, the end locations of the taper section located at electric field minimum locations of said TE_{10n} mode.

14. The apparatus of claim 7, the narrow section has a length of about $m\lambda_z/2$, where λ_z is the wavelength of said TE_{10n} mode in the axial direction of the cavity, and m is an integer determined by the number of torches to be hosted in said cavity.

15. The apparatus of claim 7, wherein said cavity is a low Q cavity with a value less than 30,

wherein said torch module generates seeding plasma generating additional plasma without requiring microwave breakdown, and

wherein said cavity includes an exit opening to exit the hybrid arc/microwave plasma discharge, said exit opening having a larger diameter than would be possible if said torch module did not generate seeding plasma, said larger diameter exit opening resulting in a increase in the size of the plasma discharge.

16. The apparatus of claim 1, wherein said torch module includes a frame, a central electrode, and a ceramic insulator, the frame including an outer electrode which is electrically connected to the cavity, the ceramic insulator insulating the central electrode from the frame of the module and from the cavity.

17. The apparatus of claim 16, wherein said torch module frame includes openings to couple inlet gas into a gas chamber of said torch module.

18. The apparatus of claim 1, wherein the hybrid arc/microwave plasma discharge forms a column, said column reaching a height of about 6 cm and a diameter of about 2 cm.

19. The apparatus of claim 1, wherein the hybrid arc/microwave plasma torch has a density of at least 10^{13} electrons/cm^3.

20. The apparatus of claim 3, further comprising:

d) a first power supply module to power the microwave source; and

e) a second power supply module to power the torch module,

wherein the first and second power supply modules share a common transformer.

21. The apparatus of claim 20, wherein primary input power is selected from at least one of a 60Hz, 50Hz, and 400Hz AC primary power source, wherein the time average power of approximately 700W is supplied by said first power supply module, and wherein hybrid arc/microwave discharge has a cycle energy of approximately 12 J/cycle.

22. The apparatus of claim 20, wherein, the first power supply module includes a coupling capacitor of approximately 1 micro-Farad, wherein the second power supply includes a coupling capacitor of 1 micro-Farad and a limiting resistor of approximately 750 ohms, and wherein the common transformer has a turns ratio of approximately 1:25.

23. The apparatus of claim 3, wherein the cavity is dimensioned to support a TE_{10n} mode at the microwave source frequency, where n = 3, wherein the microwave frequency is approximately 2.45 GHz, and wherein the cavity includes a first section, a second section, and a third section, said first section having the dimensions of a S-band WR-284 waveguide of approximately 7.2 cm x 3.4 cm and a length of approximately 8.74 cm, said third section having the dimensions of approximately 7.2 cm x 0.5 cm and a length of

approximately 11.65 cm, said second section being a middle section, being tapered, having a width of approximately 7.2 cm, a height ranging from approximately 3.4 cm to approximately 0.5 cm, a length of approximately 11.65 cm and a slope angle of approximately 14 degrees.

24. An apparatus for supporting generation of at least one hybrid arc/microwave plasma discharge, the apparatus comprising:

a) a cavity supporting at least one of a TE mode and a TM mode at a microwave frequency; and

b) means for coupling at least one torch module to said cavity.

25. The apparatus of claim 24, wherein the means for coupling at least one torch module include a threaded portion attached to a wall of said cavity.

26. The apparatus of claim 24, wherein the dimensions of the cavity support a TE_{10n} mode at the microwave source frequency, where n is an integer of at least 3.

27. The apparatus of claim 24, further comprising:

c) means for coupling at least one additional torch module to said cavity, wherein said torch plasma is energized by a TE mode electric field rather that by a TM mode, and wherein at least two hybrid arc/microwave plasma discharges are generated.

28. The apparatus of claim 24, wherein, said cavity includes a first wall and a second wall opposing the first wall, wherein the means for coupling is provided on the first wall of the cavity, and wherein an exit opening is defined in the second wall of the cavity at a location opposed to the location of the means for coupling.

29. The apparatus of claim 24, wherein said cavity has a narrow section, a wide section, and a tapered section arranged between the narrow and wide sections.

30. The apparatus of claim 29 wherein both the narrow section and the wide section have rectangular cross sections.

31. The apparatus of claim 30, wherein the cavity is dimensioned to support a TE_{10n} mode at the microwave source frequency, wherein n is an integer that is at least 3.

32. The apparatus of claim 28, wherein said cavity includes endwalls substantially orthogonal to the first and second walls, wherein torch plasma forming the hybrid arc/microwave plasma discharge exits the cavity from the exit opening of the second wall.

33. The apparatus of claim 32, wherein said cavity has a narrow section, a wide section, and a tapered section arranged between the narrow and wide sections,

wherein said cavity includes a narrow section defined by the additional walls, the narrow section having a height of about 5 mm, a first of the additional walls having a first opening defined therein at which the torch module is fixed, a second of the additional walls having a second opening defined therein,

wherein the second opening permits the hybrid arc/microwave plasma discharge to exit, and

wherein the first and second openings are located at one of the electric field maximum locations of the TE_{10n} mode, and the tapered section including two end locations, the end locations of the taper section located at electric field minimum locations of said TE_{10n} mode.

34. The apparatus of claim 29, the narrow section has a length of about $m\lambda_z/2$, where λ_z is the wavelength of said TE_{10n} mode in the axial direction of the cavity, and m is an integer determined by the number of torches to be hosted in said cavity.